Relevance of Zoogeographical Transition to Conservation of Fauna: Amphibians and Reptiles in the South-western Slopes of New South Wales

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ABSTRACT

Frogs and reptiles were surveyed in twelve forests on the south-western slopes of New South Wales. The location and size of the forests determined their faunal composition. Riverine forests had fewest species of reptiles and frogs. The other forests divided into eastern, central and western zones on the basis of faunal composition, the change on an east-west gradient marking the transition from coastal and montane (Bassian) fauna to inland (Eyrean) fauna. More than 75% of the recorded species reach their geographic limits within the slopes. The transition lies in the centre of the region and the fauna there was depauperate. Western forests were also depauperate, containing only 50% of the Eyrean fauna known to occur in the region and less than 25% of species found 200 km further west. The forests of the region serve principally to maintain the range of species. Most are of sufficient size to conserve the majority of their component herpetofauna, the exceptions being small western forests (c. 300 ha) that are surrounded by agriculture.

INTRODUCTION

The concept of faunal subregions within the Australian continent was first advanced by Spencer (1896), who delineated a northern Torresian, a south-eastern Bassian and a central Eyrean zone, the demarcation between the Bassian and Eyrean zones being the Great Dividing Range. Keast (1959, 1962) noted that the Spencer scheme agrees "fairly well" with the general distribution of major groups of reptiles and that there is "about a 50 per cent changeover of species . . . between coastal Sydney and the Dubbo area on the western slopes and about 150 miles inland". Cogger and Heatwole (1981) likewise conclude that reptile distributions "generally uphold the traditional view of Australia's major biogeographic subregions" although the location of boundaries varies from family to family. For amphibians, Horton (1973) and Littlejohn (1981) accepted the separation of a coastal fauna and an inland fauna in south-eastern Australia. The precise location of the boundary has been analysed for the avifauna by Kikkawa and Pearse (1969), who found the demarcation in south-eastern Australia consistently bisected the south-western slopes of New South Wales.

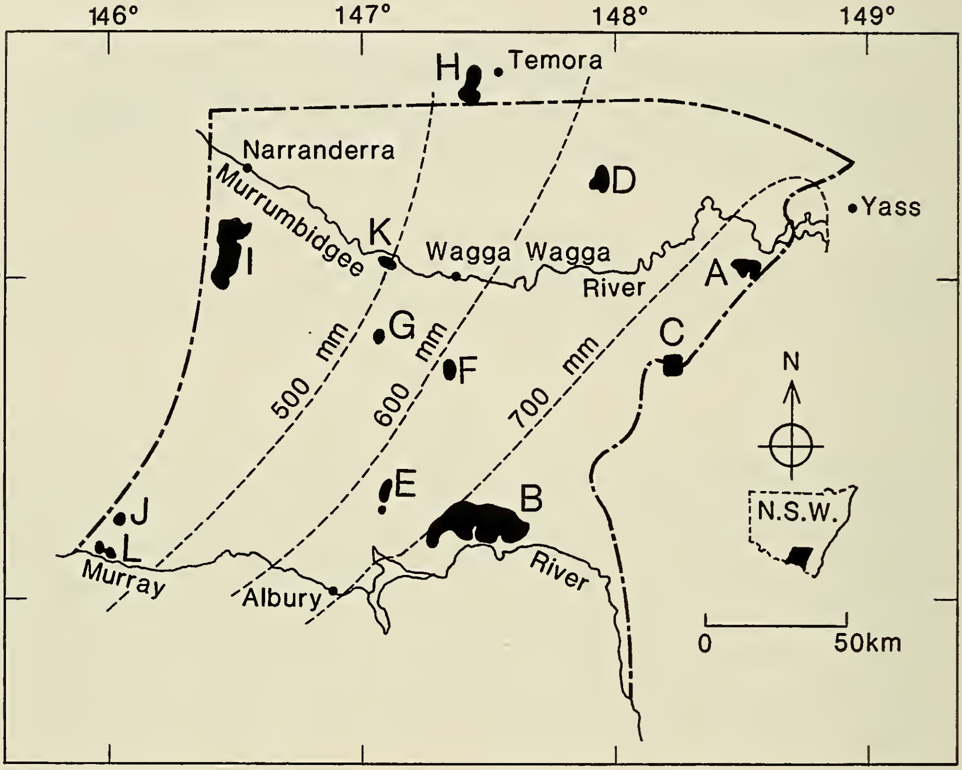

FIG. 1. Map of the south-western slopes of New South Wales showing the location of the areas surveyed, coded as in Table 1.

The south-western slopes (Fig. 1) is one of the biogeographical regions of New South Wales defined by Anderson (1968) and consistently used as the basis for representative conservation of flora. The boundaries of the regions are delineated principally by climate — for the south-western slopes, rainfall is between 400 and 900 mm per year falling predominantly in winter; winter frosts are common but snow is rare. Altitude varies from 600 m in the east (although some areas are as high as 1000 m) to 100 m in the west. Physiographically it comprises hilly, undulating and plains country.

Settlement of the region followed the expedition of Hume and Hovell in 1824, and by 1860 almost all the region was subdivided into pastoral holdings (Taylor 1959). Extensive clearing for wheat growing began soon after on the lower slopes. Typically the only land left uncleared was rocky hillsides and the higher slopes to the east where agriculture was restricted by the short growing season and high incidence of frosts. Today only 4 per cent of the region retains its original forest cover.

In this paper, we examine the effect of the zoogeographical boundary on the distribution of reptiles and amphibians in the south-western slopes of New South Wales and look at the relevance of the transition to the conservation of the herpetofauna in the region.

METHODS

Eleven forests representing a cross-section of the geographic and topographic variation in the south-western slopes, and Ingalba Nature Reserve just to the north, were surveyed (Fig. 1). The duration and times of survey are given in Table 1.

Reptiles were collected opportunistically. Most were caught by hand after sighting or searching under logs, rocks and bark. Some of the larger species were caught in Elliott traps set for small mammals. Frogs were found under logs and bark or by spotlighting around water at night, and tadpoles were collected and raised through to metamorphosis for identification. Specimens of most of the smaller species were taken and lodged in the Australian Museum. The taxonomy follows Cogger (1979).

TABLE 1. Summary of the survey of the southwestern slopes (S.F. = State Forest, N.P. =National Park, N.R. = Nature Reserve).

Code	Forest	Area (ha)	Month of survey	No. survey days	No. spp. frogs	No. spp. reptiles
A	Bungongo S.F.	2,000	Jun	7	8	6
			Jan	4	8	10
B	Dora Dora N.P.	33,000	Oct	7	6	13
	Proposal		Jan	9	8	11
C	Tumut S.F.	3,500	May	7	4	2
			Nov	2	5	9
D	Ulandra N.R.	3,000	Feb	4	5	8
			Nov	3	3	8
E	Tabletop N.R. and	1,500	Oct	8	2	10
	Benambra S.F.		Oct	3	0	7
F	Livingstone S.F.	2,000	Mar	8	3	6
G	The Rock N.R.	300	Jun-Jul	7	0	5
			Jan	3	0	4
			Mar	1	3	–
H	Ingalba N.R.	3,500	Aug	10	0	5
			Feb	6	4	2
			Mar	2	–	6
I	Buckingbong S.F.	12,000	Apr	6	5	6
			Dec	6	6	10
J	Wahgunyah S.F.	300	Aug	4	1	5
K	Berry Jerry S.F.	1,200	Apr	2	0	1
			Dec	2	3	2
L	Boomanoomana and Mulwala S.F.'s	1,500	Aug	5	5	3

RESULTS

Species lists for the twelve areas are presented in Appendix Tables 1 and 2. In all, a total of 15 species of frogs and 37 species of reptiles were found*.

Before we compare the fauna of the different forests, the factors affecting the success of surveys require appraisal.

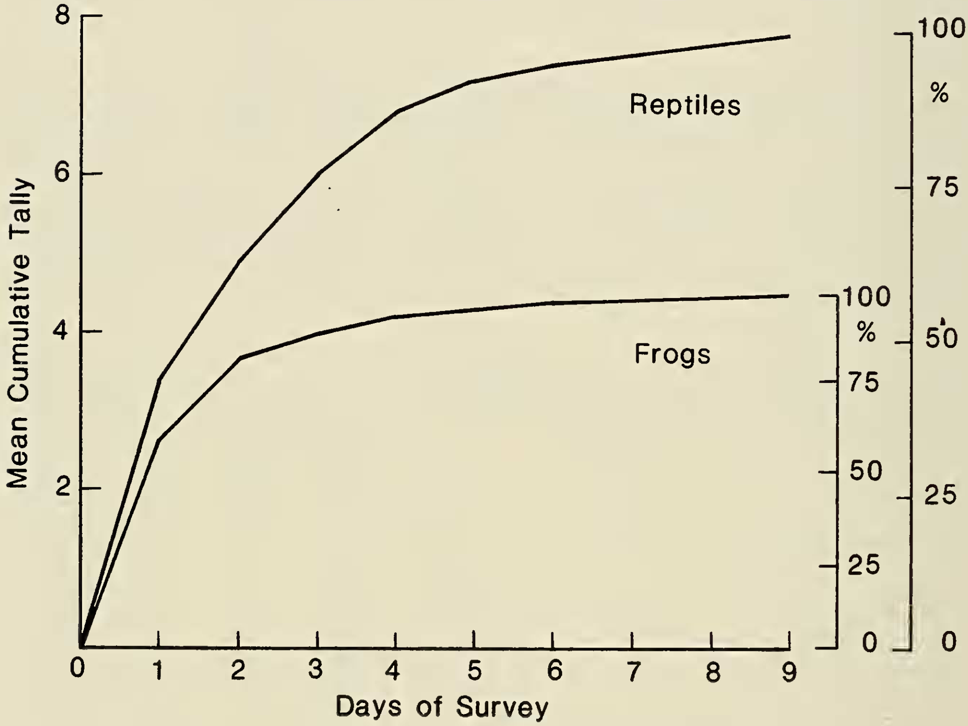

FIG. 2. Effect of effort on the number of species of frogs and reptiles found.

Effect of Effort

The effect of effort was measured by plotting the number of days of survey against the cumulative total of species of frogs and reptiles averaged over all areas (Fig. 2). In eastern forests, frogs were found quickly and easily near water, and

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* Confusion in distinguishing *Ranidella parinsignifera* from *R. signifera* through much of the survey has prevented accurate assessment of their respective distributions. Also, early collections of *Cryptoblepharus boutonii* were not identified to current taxonomic nomenclature.

and the tally of species seldom increased after the second day. In western areas the rise was slightly slower because of the wider scattering of water bodies. Reptile tallies likewise accumulated rapidly. Approximately half of the total number recorded were found on the first day and 80% by 3.5 days. Thereafter the rate slowed markedly with continuing effort gradually turning up additional species.

Effort varied between the different forests, but few species would have been added if it had been equalised across all areas. For example, Wahgunyah was surveyed for only four days, but the relationship in Fig. 2 predicts that five more days of survey would have produced only 0.7 additional species of reptiles and 0.1 species of frogs.

Effect of Season

There was no discernible effect of season on the number of species of frogs recorded (Fig. 3). Success depended on dampness of the ground and on standing free water rather than time of year. In contrast, the effect of season on reptile tallies was marked, with late spring the optimal time for survey (Fig. 3). A sinusoidal surve was fitted to the data by transforming the month of survey of *cos t*, taking November as 0° (maximum) and May as 180° (minimum) (riverine areas were excluded because of their poor faunal tallies, each point lying well below those from other areas). The 'slope' of the regression, 2.7, differed significantly from zero ($t = 3.81$, d.f. = 16, $P < 0.01$).

The effect of season was mitigated by re-surveying many of the forests (Table 1) but three were visited only once (F, K, L). In these areas, time of survey accounts at least in part for the low number of species recorded. The curve suggests that had they been surveyed in November, an additional 2 to 4 species may have been found.

T. Annable (pers. comm.) has surveyed one of the forests (F) and found 3 species of reptiles — *Morethia boulengeri, Lerista bougainvillii* and *Diplodactylus vittatus* — that we did not record. To overcome the shortfall in our data due to time of survey, these species are included in the subsequent analyses For the other two forests no additional data are available.

Effect of Forest Size

The number of species (S) of reptiles and frogs recorded in a forest increased with its area (A) in ha, such that $S = 1.8\ A^{0.25}$ ($r^2 = 0.54$) (Fig. 4). The exponent 0.25 does not differ significantly from 0.30, the exponent predicted by the thesis that the number of species doubles with a ten-fold increase in area ($t = 0.64$, d.f. = 10) (Darlington 1957, MacArthur and Wilson 1967). Large forests generally had more species than smaller forests, irrespective of their location.

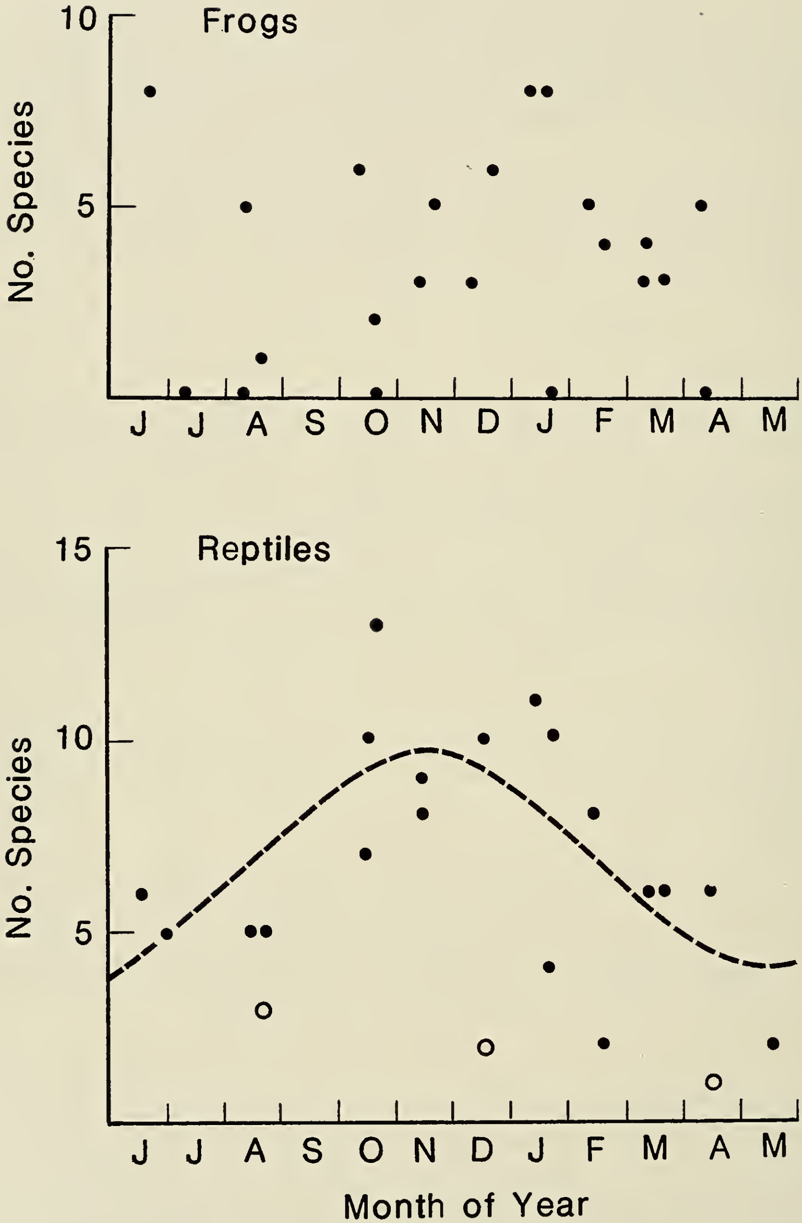

FIG. 3. Effect of season on the number of species of frogs and reptiles found (o = riverine forests).

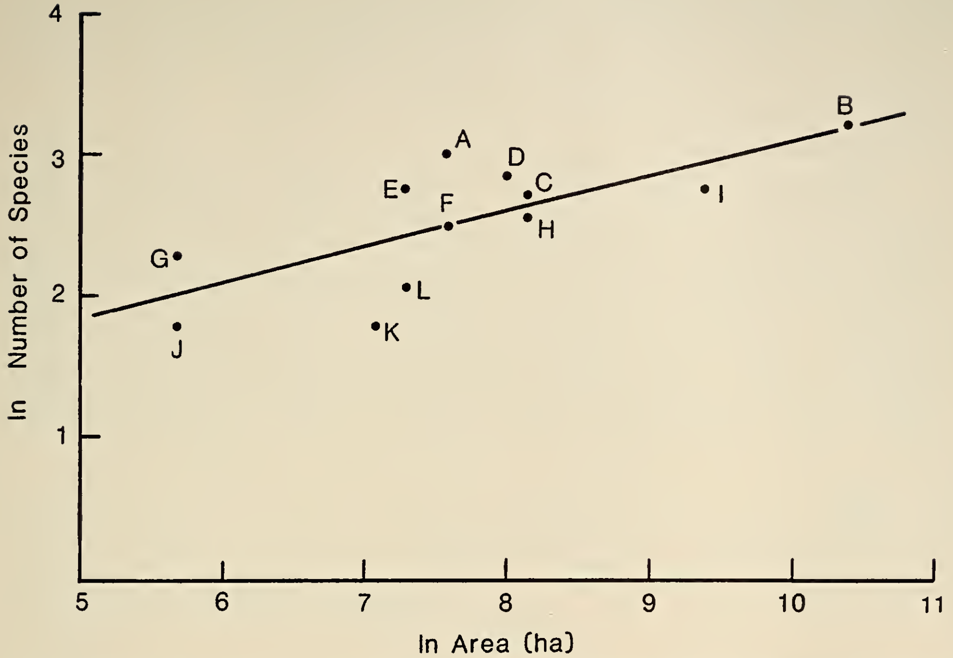

FIG. 4. Relationship between number of species of frogs and reptiles and size of forests, coded as in Table 1.

Effect of Habitat Diversity

Although no quantitative assessment was made, most forests contained a variety of habitats. All had trees with loose bark, litter, fallen logs, shrubby areas and grassy areas, open glades and dense forest, although the extent of each varied from area to area. Both eastern and central forests were hilly to mountainous, with rock outcrops, sheltered gullies and dry ridges. Western areas were more undulating, reducing the diversity associated with slope and aspect. Rocky areas were absent but forestry practices of thinning and logging provided stumps with loose bark that substituted for rock crevices for some species (e.g. *Egernia striolata*). Eastern forests had moist habitats lacking in central and western areas. Water availability was good in the east where permanent creeks were present and the incidence of swampy areas was high. In the west, watercourses were impermanent and dams scattered through the forests for stock were the principal amphibian habitat. Riverine forests offered the least habitat diversity. Litter from the river red gums was sparse, the grassy understorey offered poor shelter and the loamy, cracking soil was unsuitable for burrowing species. On the basis of habitat diversity, eastern forests could be expected to have the highest tally of species and riverine areas the lowest. These predictions are borne out in Fig. 4 where all the eastern forests (A to F) lie on or above the line of best fit, and the riverine and most of the western forests (G to L) below.

The Faunal Transition

Although the number of species recorded in a forest depended on its size and habitat diversity, the composition of the fauna varied with its location. For example, the ubiquitous *Lampropholis guichenoti* of the eastern forests was replaced by *Morethia boulengeri* in the west. A cluster analysis using Sorensen's index of similarity (Mueller-Dombois and Ellenberg 1974) was generated to explore the faunal disparity and the resulting dendrogram is shown in Fig. 5. The first separation (greatest dissimilarity) indicated the atypical nature of the riverine forests. The next fork separated out the western forests — Buckingbong, Wahgunyah, Ingalba and The Rock — from those to the east. There was only 43%

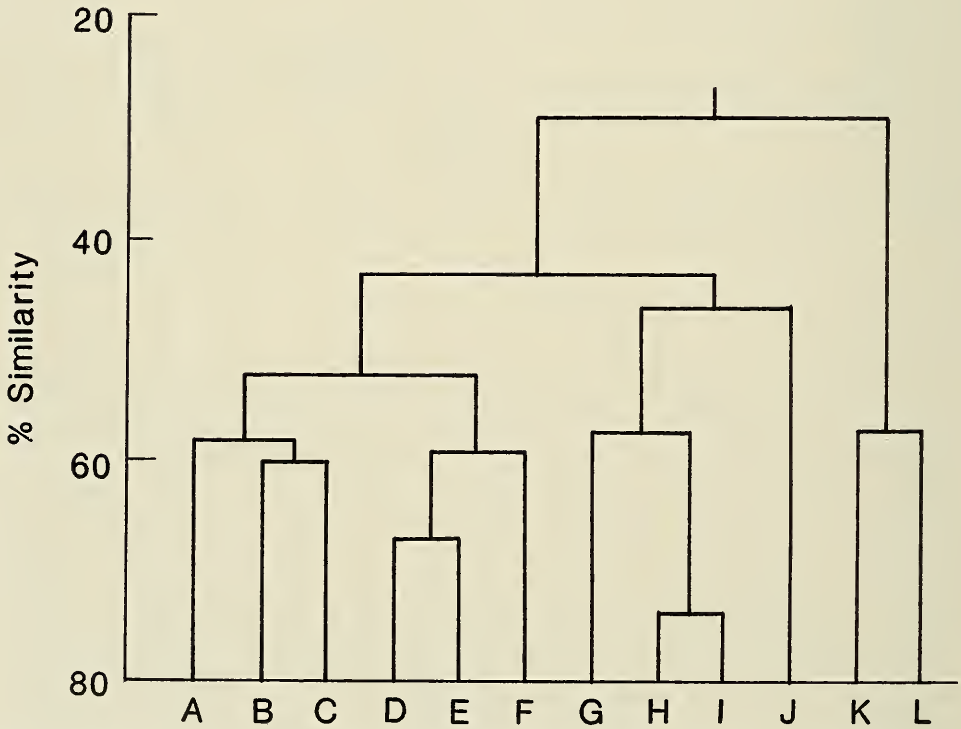

FIG. 5. Analysis of faunal similarity between forests on the south-western slopes, coded as in Table 1.

similarity between the faunas of these groups of forests. The third fork separated the mountainous eastern forests adjacent to the tablelands from the rock outcrop forests in the centre of the region.

The faunal changeover between the east and west of the region is illustrated in Tables 2 and 3 where the species have been arranged according to their presence on an east-west gradient and to their classification as coastal or montane (Bassian), inland (Eyrean), or widespread species. The classifications were based on the distribution maps in Cogger (1979) — if the major part of a species' distribution was to the west of the region it was classed as Eyrean, if to the east, Bassian. In some cases the classification was difficult. Some species with primarily a Bassian distribution extended well into the Eyrean region (e.g. *Amphibolurus barbatus Pseudonaja textilis*). These were placed the 'widespread' category. Other species did not fall neatly into either zone (e.g. *Litoria raniformis, Carlia tetradactyla*) and their placement may be questionable. However, we hope that for the majority, the classifications are generally acceptable. There were no autochthonous species.

A sharp decline in eastern species and a gradual rise in western species is is evident in these tables. The trends are graphed in Fig. 6 which illustrates the depauperate nature of both central and western forests, the central forests being particularly poor. Not only were there few species but those present were never as abundant as in similar habitats to the east and west. Hours of fruitless searching are a lingering memory of these areas.

TABLE 2. Appendix Table 1 reproduced with species of frogs classified as Bassian, Eyrean or widespread, showing (a) the decline in Bassian species as we progress westwards and (b) the low number of Eyrean species in western forests. Areas coded as in Table 1.

Species	A	B	C	D	E	F	G	H	I	J	K	L
BASSIAN												
Uperoleia marmorata	x											
Litoria booroolongensis	x	x										
Limnodynastes peronii	x	x										
Litoria ewingii		x										
Limnodynastes dumerilii	x	x	x									
Litoria verreauxii	x		x									
Pseudophryne bibroni	x	x	x	x	x							
WIDESPREAD												
Ranidella spp.	x	x	x	x	x	x	x	x	x		x	x
Litoria peronii	x	x	x	x		x		x	x		x	x
Limnodynastes tasmaniensis	x	x	x	x		x	x	x	x			x
EYREAN												
Litoria raniformis		x							x		x	x
Limnodynastes interioris				x			x	x	x			
Uperoleia rugosa									x	x		
Limnodynastes fletcheri												x

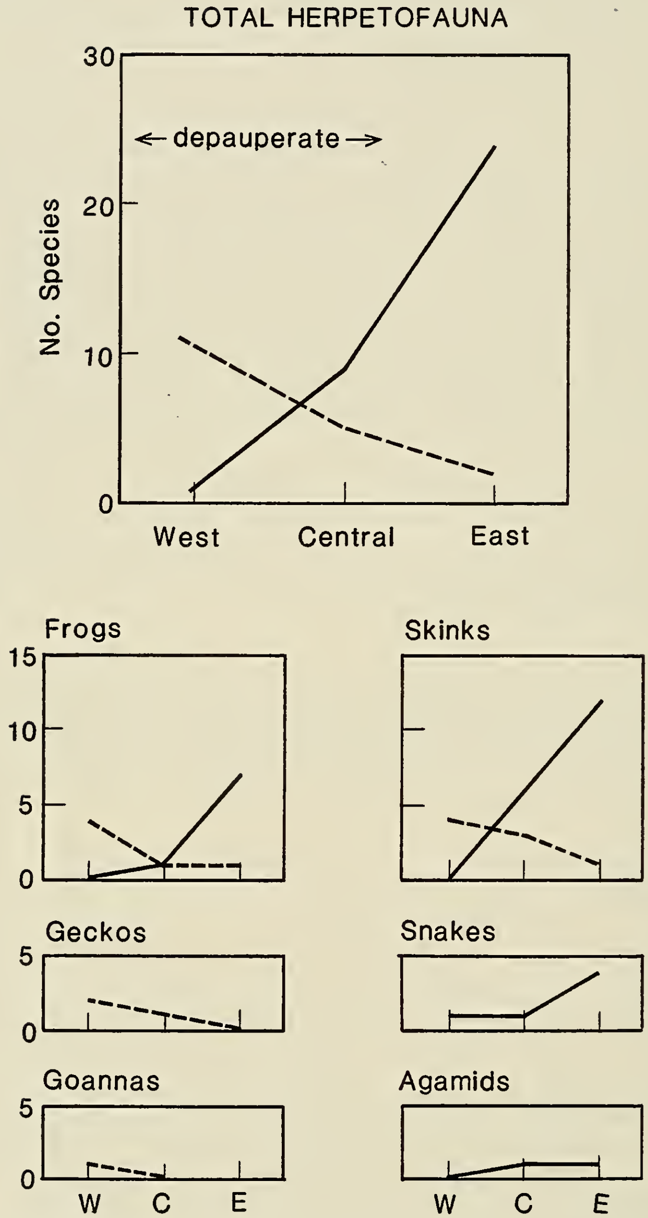

FIG. 6. Numbers of Bassian (———) and Eyrean (...... ...) species in eastern, central and western zones of the south-western slopes.

The changeover was not uniform within the different groupings of herpetofauna (Fig. 6). Although frogs and skinks followed the transition described above, with Bassian and Eyrean faunas overlapping in the centre of the region, all geckos were either Eyrean or widespread species — no Bassian geckos were recorded. Conversely, all snakes and agamids were Bassian or widespread species. No Eyrean species were found in the forests surveyed.

TABLE 3. Appendix Table 2 reproduced with species of reptiles (excluding turtles) classified as Bassian, Eyrean or widespread, showing the decline in Bassian species and increase in Eyrean species from east to west. Areas coded as in Table 1.

Species	A	B	C	D	E	F	G	H	I	J	K	L
BASSIAN												
Lampropholis delicata	x											
Leiolopisma trilineata	x											
Egernia whitii	x											
Tiliqua nigrolutea	x											
Drysdalia coronoides	x											
Typhlina nigrescens		x										
Cryptophis nigrescens		x										
Hemiergis decresiensis	x	x	x									
Leiolopisma platynota		x	x									
Sphenomorphus tympanum	x	x	x	x								
Egernia cunninghami		x		x								
Lampropholis guichenoti	x	x	x	x	x							
Lerista bougainvillii		x				x						
Amphibolurus muricatus		x	x	x	x	x						
Ctenotus taeniolatus		x		x	x	x						
Carlia tetradactyla			x	x	x	x						
Pseudechis porphyriacus	x	x	x	x	x	x					x	x
WIDESPREAD												
Varanus varius		x	x	x	x	x	x	x	x			
Pseudonaja textilis		x			x			x	x	x		
Amphibolurus barbatus					x			x	x			
Egernia striolata	x	x		x	x			x				
Diplodactylus vittatus		x			x	x		x				
Tiliqua scincoides	x	x							x			
Ctenotus robustus					x							
Demansia psammophis					x							
Lialis burtonis							x					
EYREAN												
Morethia boulengeri			x	x	x	x	x	x	x	x		
Trachydosaurus rugosus				x								
Phyllodactylus marmoratus				x	x		x			x	x	
Cryptoblepharus sp./spp.						x	x	x	x	x		
Diplodactylus intermedius							x		x	x		
Varanus gouldii							x		x			
Lerista muelleri								x	x			
Ctenotus strauchii								x	x			

TABLE 4. Frogs and reptiles known to occur on the southwestern slopes but not found during the survey, classified as Bassian, Eyrean or widespread species.

Species	Basssian	Widespread	Eyrean	Source*
Frogs				
Neobatrachus pictus			x	A.M., A.N.W.C.
Ranidella sloanei			x	Littlejohn 1958
Reptiles				
Gehyra variegata			x	Annable
Underwoodisaurus milii		x		Annable
Aprasia parapulchella	x			Cogger 1979
Delma impar	x			Kluge 1974
Delma inornata			x	Kluge 1974, A.M., A.N.W.C., Annable
Pygopus lepidopodus	x			Annable
Pygopus nigriceps			x	Kluge 1974
Physignathus lesueurii	x			Annable
Menetia greyi			x	Annable
Typhlina australis			x	A.M. (1892)
Typhlina bituberculata			x	Annable
Typhlina proxima			x	Annable
Python spilotes		x		Annable
Austrelaps superbus	x			Annable
Furina diadema		x		Annable
Notechis scutatus		x		Annable
Unechis gouldii			x	Annable
Vermicella annulata		x		A.M. (1889-94), Annable
No of species	5	5	10	

* Abbreviations in sources: A.M. — Australian Museum (date if last century); A.N.W C — Australian National Wildlife Collection.

Table 4 lists species not found during the surveys but known to occur in the region, based on the literature, museum collections and the personal collections of T. Annable. The species were classified as Bassian, Eyrean or widespread as before, and 50% were Eyrean forms. These Eyrean species could be absent from forests in the region, but it is perhaps more likely that the cryptic behaviour and low densities of some of the species (e.g. blind snakes, pygopodids) may indicate insufficient sampling rather than a real absence.

Even if these species are present, the western forests are still depauperate when compared with areas further inland. For example, the number of species is less than half that found in Round Hill Nature Reserve, 200 km to the north-west.

DISCUSSION

The prime attribute determining the species richness of a forest was its size, but because the slopes encompass a transition between Bassian and Syrean faunas, the species composition varied with location on an east-west gradient. Only 25%

of the fauna were widespread species. The remaining 75% reach their geographic limits within the south-western slopes.

The boundary between the two major faunas closely approximates the demarcation noted by Kikkawa and Pearse (1969) for birds, but as found by Cogger and Heatwole (1981), the site of the transition differed between families of reptiles. Skinks, the most numerous group, matched the transition described above. Geckos were represented by Eyrean species only, suggesting the transition lies farther to the east for this group. These reptiles are principally Eyrean; true Bassian geckos are few. Agamids likewise have evolved primarily within the Eyrean zone, yet no Eyrean species were found in the slopes. Instead the family was represented there by "modified Bassian" species, and the transition zone for the group lies to the west. Cogger and Heatwole (1981) attribute these differences between families to differences in their patterns of adaptive radiations. The resultant is a broad zone of transition, and the fauna across the zone is markedly depauperate.

The transition is typical of the abutment of regional faunas — an 'overlapping of faunal elements, with progressive subtractions, in both directions' so that 'the transitional faunas are usually depauperate' (Darlington 1957). The reason for the transition is thought to be climate (e.g. Keast 1959). The eastern, central and western zones of the south-western slopes delimited by the 700 mm and 600 mm isohyets coincide with the divisions derived on the basis of faunal similarity of the forests (Fig. 1).

We have no estimates of the density or population size of any of the species in the forests. The number of sightings both within and between species varies according to their behaviour patterns and on ambient conditions. Very little is known of the home range requirements of Australian herpetofauna generally, but Turner *et al.* (1969) predict that small insectivorous lizards weighing 3 to 10 g will range over 0.05 ha to 0.15 ha. Frogs and small snakes may have ranges of the same order of magnitude. Small species therefore will reach high densities in a forest whose size is measured in thousands of hectares, provided habitat is well represented. In these circumstances, if a species was recorded in a forest, it is likely that its numbers are sufficient to represent that species' conservation there.

For larger species of reptiles, more care is required. The large skinks and agamids are omnivorous or totally herbivorous and have relatively small home ranges, comparable in size to those of smaller insectivorous reptiles. For example, the bearded dragon *Amphibolurus vitticeps* has a calculated home range of 1.8 ha (Badham 1971), less than half the 4.5 ha predicted by Turner *et al.'s* (1969) equation. Yet the large skinks and agamids were never common in forests. They appear to prefer open woodland where because the incidence of solar radiation is higher, they can reach activity temperatures more rapidly. They would therefore not be disadvantaged in pastoral country, but the extensive clearing and agriculture in the west of the region would substantially restrict their distribution.

Large carnivorous species range over disproportionately large areas. For example, the home ranges of *Varanus gouldii* on Kangaroo Island averaged 25 ha compared with 14 ha predicted by Turner *et al* (1969) equation (Green and King 1978). A *Varanus varius* monitored by radio telemetry had a calculated home range (based on three 'capture' points per day) of 300 ha (data from Stebbins and Barwick 1968) compared with a predicted 74 ha. Hence the area of The Rock approximates the home range of one large lace monitor.

In the wheat belt of Western Australia, Kitchener *et al.* (1980) recorded sand goannas, with one exception, only on reserves larger than 1500 ha and they recommended that this area be taken as the minimum reserves size for conservation of lizards. In the wheat-belt of the south-western slopes, all but three forests are smaller than 1500 ha. Buckingbong is the only forest of any size, equalling in area the sum of all the other forests in the west of the region. Many of the other forests are less than 400 ha, and all are disjunct and surrounded by agriculture.

The forests of the central zone are also isolated but the intervening country is principally pastoral land. The area surveyed (65 km^2) represents about a quarter of the remaining forest in this zone.

In the east, the forests are much more extensive. The area surveyed was 385 km^2 and there is at least three times as much forest again. In addition many of the forests are joined by corridors of similar country.

We conclude, therefore, that the south-western slopes contains marginal representation of two faunas across a zone of transition, and that the forests in the region serve more to maintain the range of species than to provide core conservation areas. In the east of the region, the extent of forests allows us to be confident of the conservation of fauna there. However, in the west the fauna is depauperate, dispersal is restricted by agriculture, and the majority of the forests are small, casting doubt on their value for conservation. In the wheat country, only Buckingbong may be large enough to preserve its total herptofauna.

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APPENDIX 1. List of frogs collected in forests on the southwestern slopes coded as in Table 1.

Species	A	B	C	D	E	F	G	H	I	J	K	L
Leptodactylidae												
*Limnodynastes convexiusculus**			?									
Limnodynastes dumerilii	x	x	x									
Limnodynastes fletcheri												x
Limnodynastes interioris				x			x	x	x			
Limnodynastes peronii	x	x										
Limnodynastes tasmaniensis	x	x	x	x		x	x	x	x			x
Pseudophryne bibronii	x	x	x	x	x							
Ranidella spp.	x	x	x	x	x	x	x	x	x		x	x
Uperoleia marmorata	x											
Uperoleia rugosa									x	x		
Hylidae												
Litoria booroolongensis	x	x										
Litoria ewingii		x										
Litoria peronii	x	x	x	x		x		x	x		x	x
Litoria raniformis		x							x		x	x
Litoria verreauxii	x		x									
TOTAL	9	9	6	5	2	3	3	4	6	1	3	5

**Limnodynastes convexiusculus* — a specimen collected in Tumut State forest has tentatively been identified as this species by the Australian Museum (R87657), despite its range being tropical coastal Australia. We suspect it to be a variant of *Limnodynastes tasmaniensis* and have not included it in subsequent analyses.

APPENDIX 2. List of reptiles collected in forests on the southwestern slopes coded as in Table 1.

Species	A	B	C	D	E	F	G	H	I	J	K	L
Chelonidae												
Chelodina expansa												x
Chelodina longicollis											x	
Emydura macquarii												x
Gekkonidae												
Diplodactylus intermedius							x		x	x		
Diplodactylus vittatus		x			x			x				
Phyllodactylus marmoratus				x	x		x			x	x	
Pygopodidae												
Lialis burtonis							x					
Agamidae												
Amphibolurus barbatus					x			x	x			
Amphibolurus muricatus		x	x	x	x	x						
Varanidae												
Varanus gouldii							x		x			
Varanus varius		x	x	x	x	x	x	x	x			
Scincidae												
Carlia tetradactyla			x	x	x	x						
*Cryptoblepharus boutonii**						x		x				
Cryptoblepharus carnabyi							x		x	x		
Ctenotus robustus					x							
Ctenotus strauchii								x	x			
Ctenotus taeniolatus		x		x	x	x						
Egernia cunninghami		x		x								
Egernia striolata	x	x		x	x			x				
Egernia whitii	x											
Hemiergis decresiensis	x	x	x									
Lampropholis delicata	x											
Lampropholis guichenoti	x	x	x	x	x							
Leiolopisma platynota		x	x									
Leiolopisma trilineata	x											
Lerista bougainvillii		x										
Lerista muelleri								x	x			
Morethia boulengeri			x	x	x		x	x	x	x		
Sphenomorphus tympanum	x	x	x	x								
Tiliqua nigrolutea	x											
Tiliqua scincoides	x	x							x			
Trachydosaurus rugosus				x								
Typhlopidae												
Typhlina nigrescens		x										
Elapidae												
Cryptophis nigrescens		x										
Demansia psammophis					x							
Drysdalia coronoides	x											
Pseudechis porphyriacus	x	x	x	x	x	x					x	x
Pseudonaja textilis		x			x			x	x	x		
TOTAL	11	16	9	12	14	6	7	9	10	5	3	3

*Specimens were not taken from these areas and identification to current taxa within the previous species *Cryptoblepharus boutonii* is not possible.